14737 - Unveiling the nature of the only main-sequence pulsar CU Vir

Cycle: 24, Proposal Category: GO

(UV Initiative)

(Availability Mode: SUPPORTED)

INVESTIGATORS

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VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) V-CU-VIR	STIS/CCD STIS/FUV-MAMA	1	19-Jul-2017 16:00:14.0	yes
02	(1) V-CU-VIR	STIS/CCD STIS/FUV-MAMA	1	19-Jul-2017 16:00:15.0	yes
03	(1) V-CU-VIR	STIS/CCD STIS/FUV-MAMA	1	19-Jul-2017 16:00:17.0	yes
04	(1) V-CU-VIR	STIS/CCD STIS/FUV-MAMA	1	19-Jul-2017 16:00:18.0	yes

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
05	(1) V-CU-VIR	STIS/CCD STIS/FUV-MAMA	1	19-Jul-2017 16:00:19.0	yes
51	(1) V-CU-VIR	STIS/CCD STIS/FUV-MAMA	1	19-Jul-2017 16:00:20.0	yes

6 Total Orbits Used

ABSTRACT

CU Vir is one of the most enigmatic stars of the upper part of the main sequence. It has been the first main sequence star that showed regular radio pulses persisting over decades, resembling the radio lighthouse of pulsars and interpreted as auroral radio emission like planets. The explanation of this effect requires relatively strong stellar wind, which is not predicted theoretically. Moreover, CU Vir, being an unusually fast rotator, belongs to a rare group of magnetic chemically peculiar stars that show rotation period variations caused by torsional oscillations. Last but not least, CU Vir light variability is not yet understood. The HST STIS observations are key to resolve all these problems by studying spectroscopic UV wind and auroral signatures as function of rotational phase. Moreover, these observations will have a broad impact on the physics of stellar and exoplanetary magnetospheres, they will provide insight in the evolution of rotational velocities, and lead to understanding of the light variability of chemically peculiar stars.

OBSERVING DESCRIPTION

To sufficiently cover the rotational period of the star, we need 5 UV spectra observed at different rotational phases. This will enable us to detect the wind lines, that may be visible in specific phases only. This will also enable us to unambiguously detect the auroral lines and study the flux variability.

As the star is relatively bright, high-resolution observation using the FUV-MAMA detector is possible, which also avoids the safety limit of STIS/MAMA detectors. For the Phase II proposal we selected a slightly different configuration which provides a higher S/N. The star is strictly periodically variable, consequently we selected the observation with maximum flux from IUE data. The IUE observations completely cover the phase diagram of the star. With the E140H grating and 31X0.05NDA slit, we derive for i1380 an acceptable S/N ratio of about 30 during a 220 s exposure (using STIS Spectroscopic ETC, http://etc.stsci.edu/etc/input/stis/spectroscopic/, ETC Request ID: STIS.sp.824458). Thanks to the neutral density filter the derived total count rate per image (118955) does not exceed the bright limit 200000 counts per second. The star is strictly periodically

variable as evidenced from decades of optical observations, which are correlated with the UV observations (2011A&A...534L...5M, 2012A&A...537A..14K). A similar calculation for c1598 gives a S/N ratio of about 22 during a 301 s exposure and the derived total count rate per image of 62 000, which is safe for MAMA detector (STIS.sp.824460). The final expected S/N is sufficient for the detection of the wind lines and of the flux variability, because the expected minimum amplitude of flux variations in FUV regions is about 30 %. The requested resolution in FUV is high enough to detect and resolve individual lines and line blends, enabling to reveal individual sources of the light variability, determine the abundances, and compare them with that derived from the optical analysis (Kochukhov et al. 2014, A&A, 565, A83). The differences will reveal the vertical abundance gradients. The gratings are selected to cover the selected wind lines (Si vi and N vi) as well as a large number of forbidden lines to detect the auroral emission.

The target is the brightest object within 5 x 5 arcsecond search area. Therefore, we can acquire the target directly. Assuming V=5.02 mag and Castelli-Kurucz Models B8V 12000 4.0 we derive with F25ND5 slit S/N = 69 for a 5 s exposure (STIS.ta.824079).

The source is too bright to perform ACQ/PEAK without dispersive element (the derived exposure time derived suing STIS Target acquisition ETC is by three orders of magnitude lower than the minimum exposure time). Using ETC we derive for G230LB grating and 31X0.05NDA slit and a typical flux of 1x10^-10 erg/s/cm^2/A at 2500 A the S/N = 64 for a 1s exposure (STIS.sp.824053). The ETC show low electrons per pixel due to background (0.0095), which should not be a problem for ACQ/PEAK. The Time to Saturation = 11.48 s.

The currently available IUE data have too low resolution and insufficient S/N to detect the weak wind and auroral lines. For example, the region of the complex Si iv wind doublet is described by only few (about 8) data points in low-resolution data, while the data with higher resolution are too noisy for the line shape analysis.

The data precision is also sufficient to detect small period changes using old low-resolution IUE data. Even if the uncertainty of the time measurement would be 1 hour (approx 0.04 days), then the long time delay between HST and IUE observations 33 years=12 000 days means that with the period of 0.52 days the period uncertainty would be 0.04/12 000x0.52=2x10^-6 days, i.e., by the order of magnitude lower than the known period change. The improvement of the rotational period variations of CU Vir will lead to detection of additional modes of torsional oscillations.

We plan to split all observations in two to avoid problems with cosmic rays. The estimated visibility is 54 min per orbit (according to APT). To fully cover the rotational period we need 5 identical iterations, i.e., in total 5 orbits. The total requested time per one orbit is given in the following table (according to STIS Instrument Handbook for Cycle 24):

Orbit 1 (Visit 1)

Guide-Star acquisition	6 min
Target acquisition	6 min
ACQ/PEAK	6 min
Scientific exposure E140H (i1380)	220 s
E140H overhead	8+1 min
Scientific exposure E140H (c1598)	301 s
E140H overhead	8+1 min

The exposures completely fill the orbit (this was checked using the Orbit Planner tool).

The run is schedulable (checked using Visit Planner tool).

The Bright Object Checking revealed that only the target is not safe. This is caused by the use of worst-case scenario. The detailed calculation using the ETC shows that the object is safe.

Visit

Proposal 14737, phase00 (01), failed Wed Jul 19 20:00:20 GMT 2017

Diagnostic Status: Warning

Scientific Instruments: STIS/CCD, STIS/FUV-MAMA

Special Requirements: Period 0.52070095 D AND ZERO-PHASE HJD2457754.38135

Diagnostics

(phase00 (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

Fixed Targets

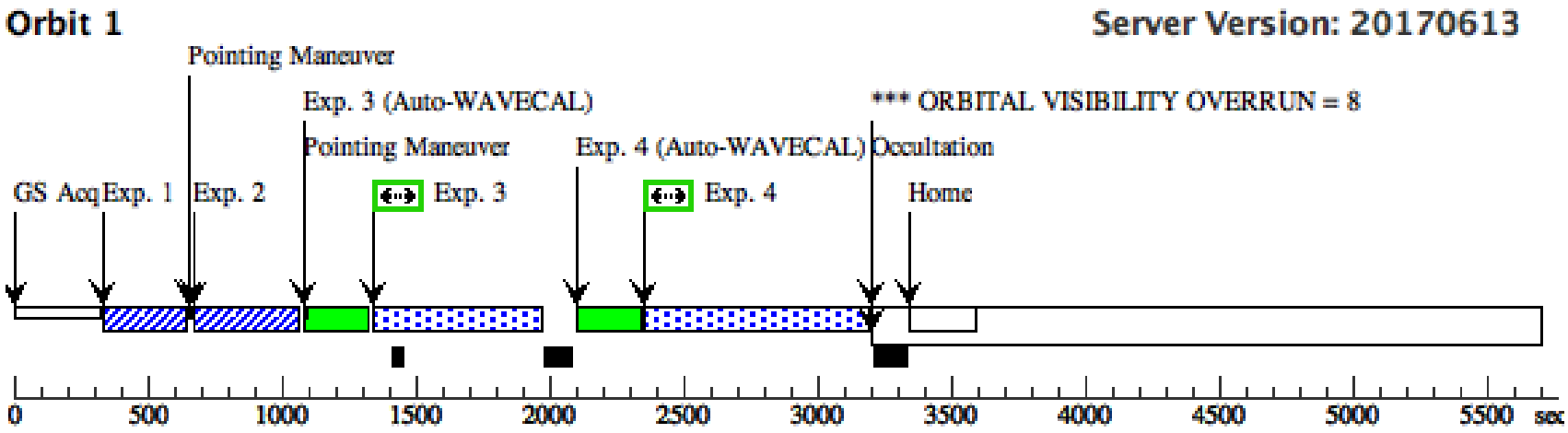
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V-CU-VIR	RA: 14 12 15.8055 (213.0658562d)	Proper Motion RA: -42.59 mas/yr	V=5.02+/-0.05	Reference Frame: ICRS
	Alt Name1: HD124224	Dec: +02 24 33.95 (2.40943d)	Proper Motion Dec: -26.70 mas/yr	maximum flux at 1500 A is 2.3e -10 erg/cm^2/s/A	
		Equinox: J2000	Epoch of Position: 2000		

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ (STIS.ta.824079)	(1) V-CU-VIR	STIS/CCD, ACQ, F25ND5	MIRROR		PHASE 0.88 TO 0.04	Sequence 1-4 Non-Int in phase00 (01)	5 Secs (5 Secs)	
								[==>]	***[1]***
2	ACQ/PEAK (STIS.sp.824053)	(1) V-CU-VIR	STIS/CCD, ACQ/PEAK, 31X0.05NDA	G230LB 2375 A			Sequence 1-4 Non-Int in phase00 (01)	1 Secs (1 Secs)	
								[==>]	***[1]***
3	lambda1380 (STIS.sp.824458)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1380 A			Sequence 1-4 Non-Int in phase00 (01)	567 Secs (567 Secs)	
								[==>]	***[1]***
4	lambda1598 (STIS.sp.824460)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1598 A			Sequence 1-4 Non-Int in phase00 (01)	775 Secs (775 Secs)	
								[==>]	***[1]***

Orbit Structure



Visit

Proposal 14737, phase18 (02), completed Wed Jul 19 20:00:21 GMT 2017

Diagnostic Status: Warning

Scientific Instruments: STIS/CCD, STIS/FUV-MAMA

Special Requirements: Period 0.52070095 D AND ZERO-PHASE HJD2457754.38135

Diagnostics

(phase18 (02)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

Fixed Targets

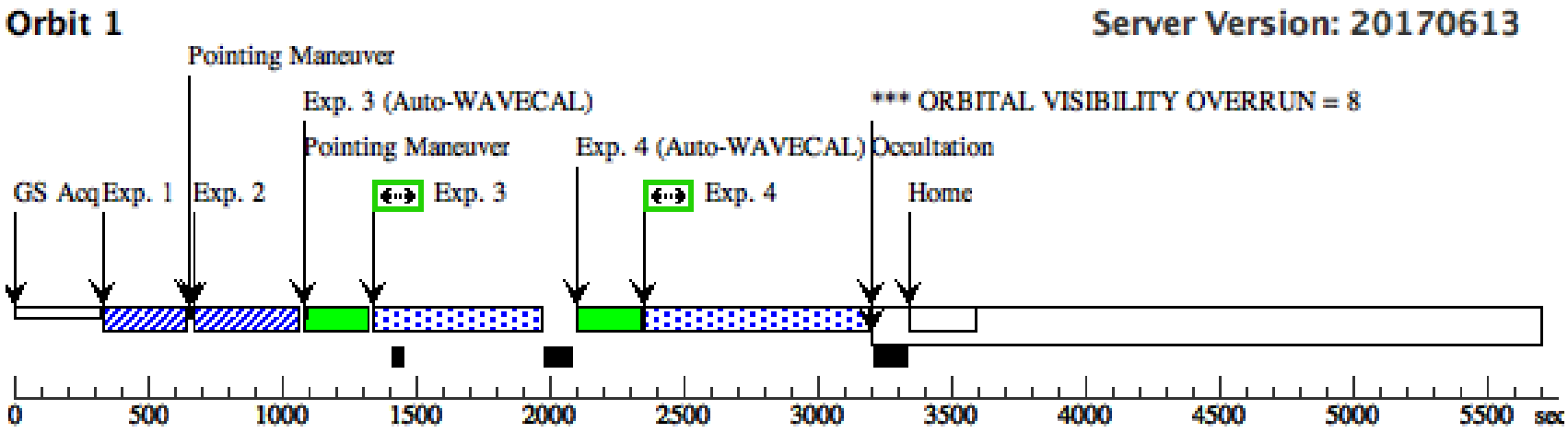
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V-CU-VIR	RA: 14 12 15.8055 (213.0658562d)	Proper Motion RA: -42.59 mas/yr	V=5.02+/-0.05	Reference Frame: ICRS
	Alt Name1: HD124224	Dec: +02 24 33.95 (2.40943d)	Proper Motion Dec: -26.70 mas/yr	maximum flux at 1500 A is 2.3e -10 erg/cm^2/s/A	
		Equinox: J2000	Epoch of Position: 2000		

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ (STIS.ta.824079)	(1) V-CU-VIR	STIS/CCD, ACQ, F25ND5	MIRROR		PHASE 0.06 TO 0.21	Sequence 1-4 Non-Int in phase18 (02)	5 Secs (5 Secs)	
								[==>]	*[1]*
2	ACQ/PEAK (STIS.sp.824053)	(1) V-CU-VIR	STIS/CCD, ACQ/PEAK, 31X0.05NDA	G230LB 2375 A			Sequence 1-4 Non-Int in phase18 (02)	1 Secs (1 Secs)	
								[==>]	*[1]*
3	lambda1380 (STIS.sp.824458)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1380 A			Sequence 1-4 Non-Int in phase18 (02)	567 Secs (567 Secs)	
								[==>]	*[1]*
4	lambda1598 (STIS.sp.824460)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1598 A			Sequence 1-4 Non-Int in phase18 (02)	775 Secs (775 Secs)	
								[==>]	*[1]*

Orbit Structure



Visit

Proposal 14737, phase32 (03), completed Wed Jul 19 20:00:21 GMT 2017

Diagnostic Status: Warning

Scientific Instruments: STIS/CCD, STIS/FUV-MAMA

Special Requirements: Period 0.52070095 D AND ZERO-PHASE HJD2457754.38135

Diagnostics

(phase32 (03)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

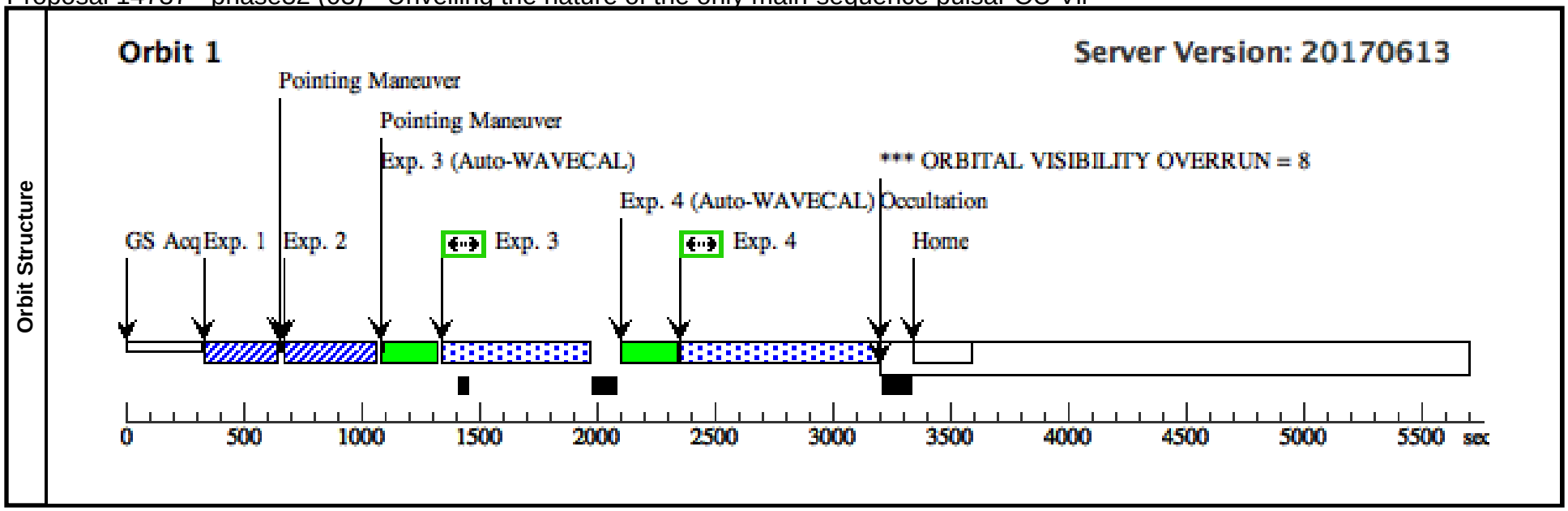
Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V-CU-VIR	RA: 14 12 15.8055 (213.0658562d)	Proper Motion RA: -42.59 mas/yr	V=5.02+/-0.05	Reference Frame: ICRS
	Alt Name1: HD124224	Dec: +02 24 33.95 (2.40943d)	Proper Motion Dec: -26.70 mas/yr	maximum flux at 1500 A is 2.3e -10 erg/cm^2/s/A	
		Equinox: J2000	Epoch of Position: 2000		

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ (STIS.ta.824079)	(1) V-CU-VIR	STIS/CCD, ACQ, F25ND5	MIRROR		PHASE 0.25 TO 0.31	Sequence 1-4 Non-Int in phase32 (03)	5 Secs (5 Secs)	
								[==>]	***[1]***
2	ACQ/PEAK (STIS.sp.824053)	(1) V-CU-VIR	STIS/CCD, ACQ/PEAK, 31X0.05NDA	G230LB 2375 A			Sequence 1-4 Non-Int in phase32 (03)	1 Secs (1 Secs)	
								[==>]	***[1]***
3	lambda1380 (STIS.sp.824458)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1380 A			Sequence 1-4 Non-Int in phase32 (03)	567 Secs (567 Secs)	
								[==>]	***[1]***
4	lambda1598 (STIS.sp.824040)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1598 A			Sequence 1-4 Non-Int in phase32 (03)	775 Secs (775 Secs)	
								[==>]	***[1]***


Orbit Structure
Orbit 1
Server Version: 20170613
Pointing Maneuver
Pointing Maneuver
Exp. 3 (Auto-WAVECAL)
*** ORBITAL VISIBILITY OVERRUN = 8
Exp. 4 (Auto-WAVECAL)
Occultation
GS Acq
Exp. 1
Exp. 2
Exp. 3
Exp. 4
Home
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec

Visit

Proposal 14737, phase58 (04), scheduled Wed Jul 19 20:00:21 GMT 2017

Diagnostic Status: Warning

Scientific Instruments: STIS/CCD, STIS/FUV-MAMA

Special Requirements: Period 0.52070095 D AND ZERO-PHASE HJD2457754.38135

Diagnostics

(phase58 (04)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

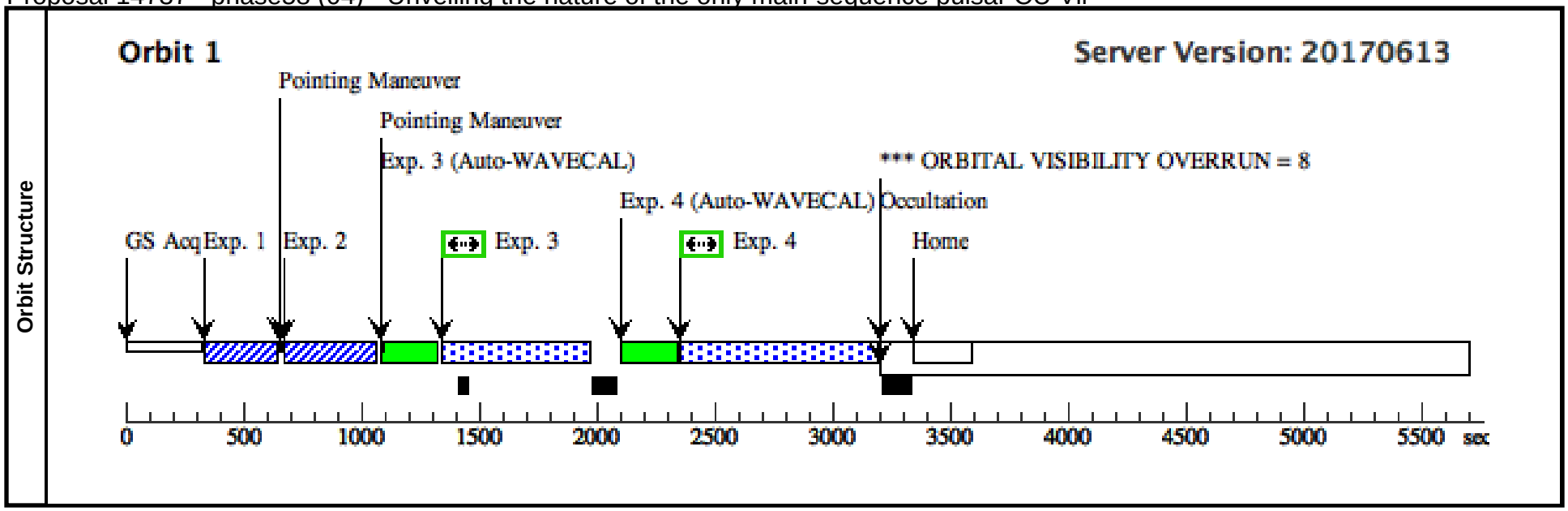
Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V-CU-VIR	RA: 14 12 15.8055 (213.0658562d)	Proper Motion RA: -42.59 mas/yr	V=5.02+/-0.05	Reference Frame: ICRS
	Alt Name1: HD124224	Dec: +02 24 33.95 (2.40943d)	Proper Motion Dec: -26.70 mas/yr	maximum flux at 1500 A is 2.3e -10 erg/cm^2/s/A	
		Equinox: J2000	Epoch of Position: 2000		

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ (STIS.ta.824079)	(1) V-CU-VIR	STIS/CCD, ACQ, F25ND5	MIRROR		PHASE 0.46 TO 0.61	Sequence 1-4 Non-Int in phase58 (04)	5 Secs (5 Secs)	
								[==>]	***[1]***
2	ACQ/PEAK (STIS.sp.824053)	(1) V-CU-VIR	STIS/CCD, ACQ/PEAK, 31X0.05NDA	G230LB 2375 A			Sequence 1-4 Non-Int in phase58 (04)	1 Secs (1 Secs)	
								[==>]	***[1]***
3	lambda1380 (STIS.sp.824458)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1380 A			Sequence 1-4 Non-Int in phase58 (04)	567 Secs (567 Secs)	
								[==>]	***[1]***
4	lambda1598 (STIS.sp.824460)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1598 A			Sequence 1-4 Non-Int in phase58 (04)	775 Secs (775 Secs)	
								[==>]	***[1]***


Orbit Structure
Orbit 1
Server Version: 20170613
Pointing Maneuver
Pointing Maneuver
Exp. 3 (Auto-WAVECAL)
*** ORBITAL VISIBILITY OVERRUN = 8
Exp. 4 (Auto-WAVECAL)
Occultation
GS Acq
Exp. 1
Exp. 2
Exp. 3
Exp. 4
Home
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec

Visit

Proposal 14737, phase75 (05), completed Wed Jul 19 20:00:21 GMT 2017

Diagnostic Status: Warning

Scientific Instruments: STIS/CCD, STIS/FUV-MAMA

Special Requirements: Period 0.52070095 D AND ZERO-PHASE HJD2457754.38135

Diagnostics

(phase75 (05)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

Fixed Targets

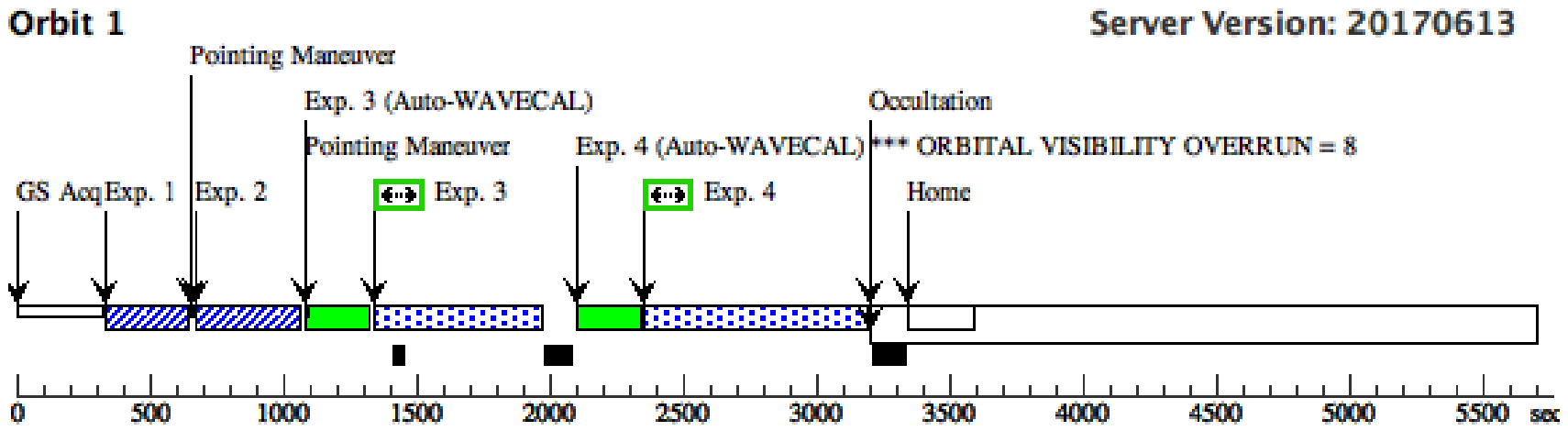
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V-CU-VIR	RA: 14 12 15.8055 (213.0658562d)	Proper Motion RA: -42.59 mas/yr	V=5.02+/-0.05	Reference Frame: ICRS
	Alt Name1: HD124224	Dec: +02 24 33.95 (2.40943d)	Proper Motion Dec: -26.70 mas/yr	maximum flux at 1500 A is 2.3e -10 erg/cm^2/s/A	
		Equinox: J2000	Epoch of Position: 2000		

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ (STIS.ta.824079)	(1) V-CU-VIR	STIS/CCD, ACQ, F25ND5	MIRROR		PHASE 0.68 TO 0.74	Sequence 1-4 Non-Int in phase75 (05)	5 Secs (5 Secs)	
								[==>]	***[1]***
2	ACQ/PEAK (STIS.sp.824053)	(1) V-CU-VIR	STIS/CCD, ACQ/PEAK, 31X0.05NDA	G230LB 2375 A			Sequence 1-4 Non-Int in phase75 (05)	1 Secs (1 Secs)	
								[==>]	***[1]***
3	lambda1380 (STIS.sp.824458)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1380 A			Sequence 1-4 Non-Int in phase75 (05)	567 Secs (567 Secs)	
								[==>]	***[1]***
4	lambda1598 (STIS.sp.824460)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1598 A			Sequence 1-4 Non-Int in phase75 (05)	775 Secs (775 Secs)	
								[==>]	***[1]***

Orbit Structure



Visit

Proposal 14737, phase00 (51) Wed Jul 19 20:00:21 GMT 2017

Diagnostic Status: Warning

Scientific Instruments: STIS/CCD, STIS/FUV-MAMA

Special Requirements: Period 0.52070095 D AND ZERO-PHASE HJD2457754.38135

Diagnostics

(phase00 (51)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V-CU-VIR	RA: 14 12 15.8055 (213.0658562d)	Proper Motion RA: -42.59 mas/yr	V=5.02+/-0.05	Reference Frame: ICRS
	Alt Name1: HD124224	Dec: +02 24 33.95 (2.40943d)	Proper Motion Dec: -26.70 mas/yr	maximum flux at 1500 A is 2.3e -10 erg/cm^2/s/A	
		Equinox: J2000	Epoch of Position: 2000		

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ (STIS.ta.824079)	(1) V-CU-VIR	STIS/CCD, ACQ, F25ND5	MIRROR		PHASE 0.88 TO 0.04	Sequence 1-4 Non-Int in phase00 (51)	5 Secs (5 Secs)	
								[==>]	***[1]***
2	ACQ/PEAK (STIS.sp.824053)	(1) V-CU-VIR	STIS/CCD, ACQ/PEAK, 31X0.05NDA	G230LB 2375 A			Sequence 1-4 Non-Int in phase00 (51)	1 Secs (1 Secs)	
								[==>]	***[1]***
3	lambda1380 (STIS.sp.824458)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1380 A			Sequence 1-4 Non-Int in phase00 (51)	567 Secs (567 Secs)	
								[==>]	***[1]***
4	lambda1598 (STIS.sp.824460)	(1) V-CU-VIR	STIS/FUV-MAMA, ACCUM, 31X0.05NDA	E140H 1598 A			Sequence 1-4 Non-Int in phase00 (51)	775 Secs (775 Secs)	
								[==>]	***[1]***

Orbit Structure